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A Well Developed Case of Club Root

CABBAGE CLUB ROOT IN VIRGINIA

By Howard S. Reed

BLACKSBURG, MONTGOMERY COUNTY, VIRGINIA

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Cabbage Club Root in Virginia

HOWARD S. REED, PLANT PATHOLOGIST.

In the summer of 1909 numerous reports of disease in cabbage plants were received from southwestern Virginia. The writer made several visits to the large cabbage-producing districts in the counties of Wythe and Smyth, and found in restricted areas that the club root disease *(Plasmodiophora brassicæ)* had become a problem and was injuring the crop in certain fields. During 1909 a general survey of the situation was made and plans laid for experimental work the following year. The results of this survey and experimental work form the subject of this bulletin.

Symptoms and Appearance of the Disease.

When a field is badly infected with disease it may appear at the seedling stage, as a dwarfing of the young plants, but the fields are not usually badly

Fig. 1—Cabbage seedlings attacked by the Club Root organism.

enough infected the first season to manifest the disease until the cabbage is half grown. In districts where the disease has just begun to get a foothold, the

grower is not likely to notice any trouble, therefore, until after the first of July. At about that time it will be noticed that the plants which are being infected show a tendency to wilt on bright sunny days, although at night they recover, and do not wilt on the following day unless it is again bright and warm. Such plants may succeed in making enough growth to produce a salable cabbage, although it is somewhat undersized and slightly loose. The earlier the plant is infected with the disease, the smaller is the head produced. If the diseased plant is pulled up, one finds that it has a swollen and contorted root, in place of the fine fibrous roots of the normal plant (see front cover). This explains the wilting, when one remembers that the soil and its dissolved food substances are taken up through the fibrous roots. When the plants are infected at the seedling stage (Fig. 1) they are usually killed before the season is half over, and the infected areas may be seen entirely bare of cabbage (see figure 2). The swollen, contorted roots, which have robbed the plant of its food material, begin to decay in the soil in the latter part of the season and continue the process of decay, aided by frosts and soil bacterias, so that nothing of them is seen the following spring.

The Cause of the Disease.

There is but one agent responsible for the club root disease. This is known as *Plasmodiophora brassicæ,* an organism belonging to lowest orders of plant

Fig. 2.—The results of Cabbage Club Root upon the crop. Practically all the cabbages in the foreground have been killed by Club Root.

life, which lives as a parasite upon the roots of cabbage and related plants, like cauliflower, rutabagas, flat turnips, mustard, etc. The early stage of this fungus gains entrance to the finer roots of the plant and creeps from one cell to another, growing and reproducing itself, while it feeds upon the substance which it finds in them. This organism is exceedingly small and can be seen only by the use of a microscope with high magnifying powers. The accompanying figure shows a thin section of the cabbage root in which this fungus is present (see figure 3). Soon after the organism enters the cells of the plant, it appears to greatly increase the growth of those cells and to cause the formation of an increased amount of protoplasm and other substances which are, no doubt, favorable to the growth of the disease. This results in the enlargement of the entire root in the course of time. We have made chemical analyses of some of these roots and it appears that they are somewhat richer in certain essential elements than the roots of the healthy plants in the same field.

As the cabbage plant and its parasite reach maturity, the latter ceases active growth and begins the formation of spores which are capable of retaining their vitality through the winter and propagating the disease. The decay of the cabbage root accomplished by bacteria and other forms of life sets free these spores in the soil, and there they remain until the following spring. When conditions are again favorable for growth, as they are the succeeding spring, these spores germinate, giving rise to an active organism which is capable of again infecting a suitable host plant, such as the cabbage, and living there the same cycle as described above. In this way the cause of the disease perpetuates itself in the soil and each year injures the cabbage which is planted there.

How the Disease is Spread from Field to Field.

From what has already been said it is apparent that the transfer of soil from an infested field to any field in which cabbage or related plants are grown, is liable to infect them with the club root disease. Some of the agencies which have been observed and studied during the course of this investigation will be briefly mentioned.

Soil Carried on Cultivators and the Feet of Horses—Several well-established cases of club root were traced to the use of cultivators and plows which had previously been used in infected soil, because infected soil was adhering to the plows, or cultivator teeth. In such cases the disease appeared in the rows where the cultivator was first used. After the first few rows were passed, the infected soil had been worked off the cultivator teeth, and no further plants were affected. Other instances were found in which the cross cultivation of the

field had carried the disease from a few infected rows on one side towards the center of the field. In other cases the infected soil appeared to have been carried on the feet of horses and mules.

Infection Carried by Soil Erosion—Very pronounced cases of club root were traced to the soil which had been carried into the field by surface water flowing from infected areas. In a field belonging to Mr. Huddle, about three miles northeast of Rural Retreat, two fields had been thrown together, and all planted in cabbage in 1909. The originally upper field had produced cabbage

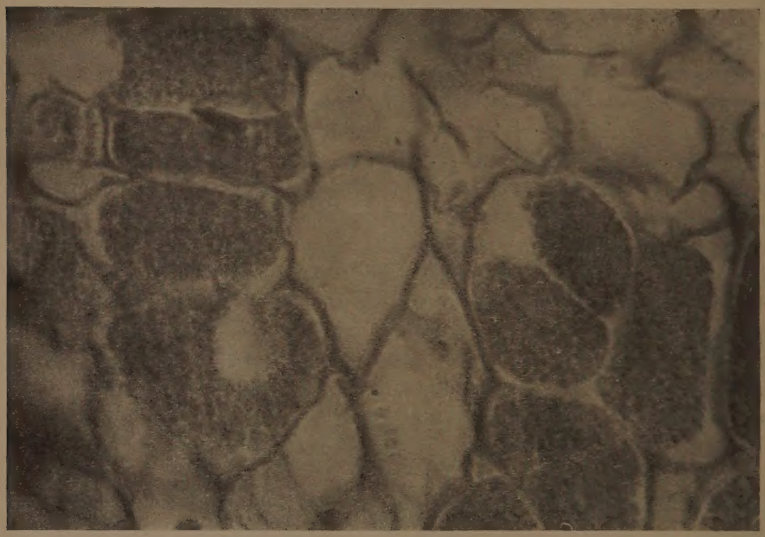

Fig. 3.—A microphotograph of a few cells of cabbage root, showing cells filled with the Club Root organism. Highly magnified.

the year before and shown a few cases of club root. During the hard rain the surface water cut some gullies at one side of the field, carrying soil from the upper infected area to the lower part of the field. Subsequently to this time club root appeared in the cabbage at the lower side of the field, only along areas which received the wash from the upper part of the field. In another instance, infected soil was carried over a road by surface drainage and brought into a large field, infecting those parts which received the silt carried in by surface streams.

Infection by Throwing Diseased Cabbages to Stock on Pasture—In another instance investigated at Rural Retreat the infection was introduced by throwing unmarketable diseased cabbage into an adjoining pasture, for cattle to eat. The following year the pasture was broken and planted to cabbage, while the former cabbage field was in wheat. In a few rows along the fence between these fields club root appeared, although not seriously. It is quite possible that the spores of the club root organism, if eaten by cattle, would survive passage of the alimentary canal and germinate in the manure. On the other hand, fragments of diseased roots lying upon the soil or trodden into the soil would decay during the winter and liberate the spores of club root disease in the soil.

Conditions which Favor the Growth of the Club Root.

Under certain environments the organism which causes club root grows much more vigorously than under others, and causes correspondingly greater injury to the cabbage. In soils which contain a large amount of organic matter (humus), and are warm and moist, the organisms find conditions very suitable for their growth. In such a soil they usually develop rapidly, and probably multiply to some extent, before they come in contact with the roots of their host plant. Thus in fields where the disease is present it is ordinarily found to be most extensive in the swales and depressions and less injurious on the higher and poorer parts of the field. There is no doubt, from the result noted in the latter part of this bulletin, that heavy applications of stable manure also make conditions favorable for the disease.

The most important circumstance from the standpoint of the grower, because most easily controlled by him, is the condition which prevails in ground where cabbage has been raised continuously for more than one year. From what has been said above concerning the club root organism, it is quite evident that a few diseased heads in the field one year may spread the disease to the entire crop of the following year. This is rendered more certain by the fact that the roots and other refuse left on the ground furnish the best possible food material for the organisms in the soil and keep them developing as long as possible in the fall of the year. From the best data obtainable, it seems to be an established fact that the club root organism has been known to survive in the soil for three years. It appears to be true, from the investigations made, that certain fields are being or have been planted to cabbbage continuously for a number of years and with consequent detriment to the present crops. This was due to the fact that bottom land, which is naturally a very desirable soil for cabbage growing, is somewhat restricted in area on many farms, and the need is felt of making the most of it for cabbage growing. This practice is dangerous in most cases unless the utmost precautions are observed to prevent the introduction of club root disease, coupled with the proper selection of fertilizers.

Experiments on Club Root Disease in the Field.

In the fall of 1909 experiments were started, looking toward field treatments which would combat the club root disease. Through the kindness of Captain J. W. Davis, whose courtesies are gratefully acknowledged, we were given the use of about one acre of ground in a field near Rural Retreat, where the disease had been prevalent in 1909.

After the removal of the crop of 1909, the land was worked with a disk harrow and kept free from weeds during the remainder of the season. On November 4th the land was measured and divided into plots of one-sixth of an acre. The plots were laid out in an approximately eastward and westward direction, extending from the low ground on the front of the field to the rising ground at the back. This made a depressed and elevated portion to each plot and afforded an opportunity to observe the effect of treatment in the moist, rich soil at the bottom, as well as the higher, better drained soil at the upper side. One plot was untreated, and served for a control of the treatment used. The plots were numbered and designated as follows:

No. 1. Received lime in the fall.

No. 2. Control Plot. (No treatment.)

No. 3. Received lime in the spring, at the same rate as No. 1.

No. 4. Received 14 per cent acid phosphate in the spring.

No. 5. Had received lime two years previous on experiment, but the amount applied was not ascertained.

No. 6. Received a dressing of stable manure in the spring.

On November 4th, 1909, unslacked lime was applied to plot No. 1, at the rate of 90 bushels per acre. On May 6th, 1910, plot No. 3 received unslacked lime at the rate of 90 bushels per acre, and plot No. 4 received 14 per cent. acid phosphate at the rate of 1,200 pounds per acre. The stable manure had been applied a few days previous to this time. The entire field was then harrowed and planted the following day. The seed used on plots Nos. 1, 2, 3 and 4 was soaked for fifteen minutes in a solution of mercuric bichloride (corrosive sublimate) at the rate of 1 part to 1,000 of water. The purpose of this was to guard against introducing the germ which causes black rot—a caution, however, which was not needed, as shown by the outcome of the experiment, since plots Nos. 5 and 6, where the seed was untreated, were not infested with black rot.

The general custom of cabbage growers in Wythe County was followed—of planting seed in the hill with a hand planter and subsequently thinning to one plant in a hill. This method, which is generally followed in the cabbage raising district of southern Virginia, has the advantage of removing the danger of

introducing "damping off" and other diseases from the seed bed. The practicability of the method has been established by long and successful use.

Not long after the plants came up, those growing in the plot receiving the stable manure showed abundant signs of club root. This was, no doubt, hastened by a period of wet weather in June. By the middle of June many plants were affected, and the accompanying illustration shows the extent of the disease in seedlings gathered June 26th (see figure 1).

During the summer the field was given good cultivation and care was taken to avoid the spread of the disease from one plot to another by careful cleaning of soil from cultivator teeth in passing from one plot to another. It soon became evident that no treatment was going to be able to overcome, entirely, the club root disease. This is probably due to the fact that the organism had become so thoroughly established in the field by continuous cultivation of cabbage for two years previous, that ordinary means did not suffice. The differences, however, were quite distinct and enable one to draw reliable conclusions regarding the effect of these treatments.

On September 8th the marketable heads of cabbage were cut and measured separately on each plot. The yields were as follows:

Plot.	*Treatment Applied*	*Yield of Cabbage*
1	Lime in the fall, 90 bushels per acre	125 lbs.
2	Nothing	100 "
3	Lime in the spring, 90 bushels per acre	100 "
4	Acid phosphate, 1,400 pounds per acre	50 "
5	Lime two years previous	400 "
6	Stable manure, 8 tons per acre	0 "

The character of the cabbage and the amounts of each plot are perhaps better shown by the accompanying illustrations than by the actual weight. (Figs. 4 and 5). Plot No. 6, which received stable manure, did not yield a single pound; in fact, all plants were dead from club root before August 1st. This result is in harmony with the effect of adding some stable manure to parts of plots Nos. 1 and 2, which was inadvertently done on a small portion at the upper end of the plots. On this part the club root disease was much worse than elsewhere in the same plot, and very few good heads were produced, although the plants were not killed outright as on plot 6. In plot No. 1 the disease was held in check fairly well by the lime added, with the exception of the lower end, where the ground was loamy and moist. No. 2 was notably poorer

than No. 1, with the difference also in their higher ground. No. 3 seemed to be poorer than No. 1, at least fewer plants survived the club root than in No. 1, although the amount of merchantable cabbage on the two plots was approximately equal. Plot No. 4 was (next to the stable manure plot) the poorest in the field. Very few plants survived the disease and only a part of the plants

Figs 4 and 5.—The yield of cabbage from different plots at Rural Retreat.

No. 1—Plot received lime in the fall.
No. 2—Plot received nothing.
No. 3—Plot received lime in the spring.
No 4—Plot received acid phosphate.
No. 5—Plot received lime two years before planting the cabbage.

made merchantable heads. Plot No. 5 was decidedly the best plot. The number of plants which survived and the number of merchantable heads maturing from them was greater than in any other plot.

Conclusions.

It thus appears that, so far as this experiment went, the use of lime is distinctly beneficial in combating club root disease in the field, and that the after effects of the lime, as shown on the plot where it was applied two years previous to the experiments, are quite marked. Acid phosphate was of little

use in combating the disease. Whether this is due to the slightly acid condition which it gives the soil, or whether it is due to the fact that the phosphate is favorable to the growth of the organisms, is not ascertained. Stable manure brings conditions which are decidedly favorable for the spread of the disease, because of the large amount of organic material which it introduces into the soil.

Recommendations.

On the basis of this work we make the following recommendations.

I. Avoid introducing any material into the field which may carry the germs of the club root from diseased fields. Guard especially against diseased soil and diseased cabbage plants.

II. Practice crop rotations which will allow at least three years between crops of cabbage, rutabagas, or turnips.

III. Apply stable manure to the crop which precedes cabbage, but not to the cabbage crop itself. If acid phosphate is applied the same rule would hold.

IV. Lime will more successfully counteract the club root disease than other substances. Apply it at the rate of 100 bushels or more per acre one or two years previous to planting the cabbage.

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